#12/Decl. 4/22/3



DOCKET NO. 69975

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | |
|---|---|
| Applicants: | Perry, et al. |
| Appln. No.: | 09/801,428 |
| Filed: | March 7, 2001 |
| Title: | DIODE-PUMPED SOLID STATE LASER IN A POLYHEDRONAL GEOMETRY |
| Examiner: | Nguyen, Joseph H. |
| Art Unit: | 2815 |

DECLARATION OF MICHAEL D. PERRY PURSUANT TO 37 C.F.R. 1.131

Hon. Commissioner for Patents
Washington, D.C. 20231

Sir:

I, Michael D. Perry, declare as follows:

1. I am currently an employee of General Atomics.

2. I am an inventor of the invention as variously described and claimed in U.S. Patent Application No. 09/801,428. I am the sole inventor of the subject matter of claim 11.

3. I declare that a laser device covered by the pending claims of U.S. Patent Application No. 09/801,428, specifically claim 11, was manufactured and tested prior to January

28, 2001. I also declare that at least prior to January 28, 2001, I recognized the inventive aspects of the laser device and that the laser device would work for its intended purpose.

4. I note that all dates present on the exhibits attached hereto have been blacked out; however, I declare that all blacked out dates are dates prior to January 28, 2001.

5. Attached as page A1 of Exhibit A is a copy of a request that was sent to VLOC by Paul Banks under my direction. The request asked for a price quotation to manufacture six laser gain mediums. Page A2 is a drawing that accompanied the request illustrating a laser gain medium. The request reflects that the laser gain medium was proprietary subject matter and that VLOC was to make no other use or dissemination of the information other than for the purpose of generating a price for fabrication. The request of page A1 and the drawing of page A2 existed prior to January 28, 2001.

6. Page A1 of Exhibit A indicates that the gain mediums were to be made from Nd:YAG at 1.4-1.5 at. % Nd doping, having a transmitted wavefront of $\lambda/8$ P-V per inch wavefront distortion. The outside faces are polished and the top, bottom and central core are to be ground. Even though ground, each ground surface provides a diffuse internal reflection to any incident light.

7. As illustrated in the drawing of page A2, each laser gain medium is to be shaped as a 7-sided polyhedron having the stated dimensions and angles. The laser beam enters the gain medium through one face of the polyhedron, internally reflects off of three faces and exits through another face. Through the illustrated configuration, the beam is reflected so that the beam propagates within approximately the original plane of incidence. Furthermore, the surfaces that the beam internally reflects are oriented at 45 degrees with respect to the beam path. Additionally, the laser gain medium includes an internal core section or hole in which there is no gain material.

8. The internal core section has several purposes, one of which is to prevent uncontrolled laser oscillation. Another purpose is to reflect pump radiation entering the gain medium from an exterior face back towards portions of the gain medium.

9. Exhibit B is the requested quotation, quotation # 024690, from VLOC to Paul Banks. This quotation was received at General Atomics prior to January 28, 2001.

10. Shortly thereafter, funding was approved and five gain mediums were ordered from VLOC prior to January 28, 2001.

11. Page C1 of Exhibit C provides an invoice for purchase order no. H028402 for the receipt of five laser gain mediums consistent with that shown in Exhibits A and B. This invoice existed and the gain mediums were delivered prior to January 28, 2001. Page C2 of Exhibit C is a receiving copy of a procurement requisition indicating that the 5 gain mediums of purchase order no. H028402 were received prior to January 28, 2001. The procurement requisition also indicates that the ordered material relates to quote # 024690 of Exhibit B.

12. Exhibit D shows a photograph of a laser gain medium as manufactured and purchased from VLOC and a corresponding diagram. The gain medium is located within a cavity including laser diode pump sources and diode focusing lens arranged about the gain medium. The laser diode pump sources provide optical pump radiation through surfaces of the gain medium that the beam internally reflects. The diagram also illustrates the laser beam path through the gain medium. The device photographed existed prior to January 28, 2001. The photograph was taken and the diagram was created prior to January 28, 2001.

13. Exhibit E is a further diagram of a laser device including the gain medium as photographed and illustrated in Exhibit D. A side view illustrates a heat sink positioned at the

top and bottom of the gain medium for use in operation. The diagram of Exhibit E was made prior to January 28, 2001.

14. Exhibit F is a copy of a memo describing computer simulations of the operation of a device illustrating in FIG. 1 of Exhibit F. The performance of three materials (Nd:YAG, Nd:YLF and Nd:$YVO_4$) was compared. Table 2 on page 4 and FIG. 3 shows these results. Simulation showed that the gain medium would work for its intended purpose.

15. Prior to January 28, 2001, under my supervision, the photographed laser device was tested and performed as expected. Attached as Exhibit G are two pages from the lab notebook of Ben Pyke. Page G1 provides the results, while pages G2-G3 describes the test setup and includes an illustration of the laser cavity of Exhibit D. According to these and other tests performed prior to January 28, 2001, the laser device worked for its intended purpose, e.g., as a laser gain medium for amplification.

16. Thus, prior to January 28, 2001, I fully appreciated the utility of the laser gain medium and that it would work for its intended purpose in a laser device.

17. I have reviewed the pending claims of the present application, and in particular, I have reviewed independent claim 11, in view of the laser gain medium described above. Therefore, I declare that a laser gain medium meeting the elements of pending claim 11 in U.S. Patent Application No. 09/801,428 physically existed prior to January 28, 2001 and that this laser gain medium worked for its intended purpose and that the invention was appreciated prior to January 28, 2001.

18. As I am advised I must, I hereby declare that all statements made herein of our my knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false

statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patents issuing thereon, or any patent to which this Declaration is directed.

4/8/03
Date

Michael D. Perry

Attachments: Exhibits A, B, C, D, E and F
69975perrydec.ama.wpd

# EXHIBIT A

**GENERAL ATOMICS**

[redacted]

ATTN: Phil Drew
VLOC

Fax # 727-375-5300

RE: Quote for Nd:YAG piece.

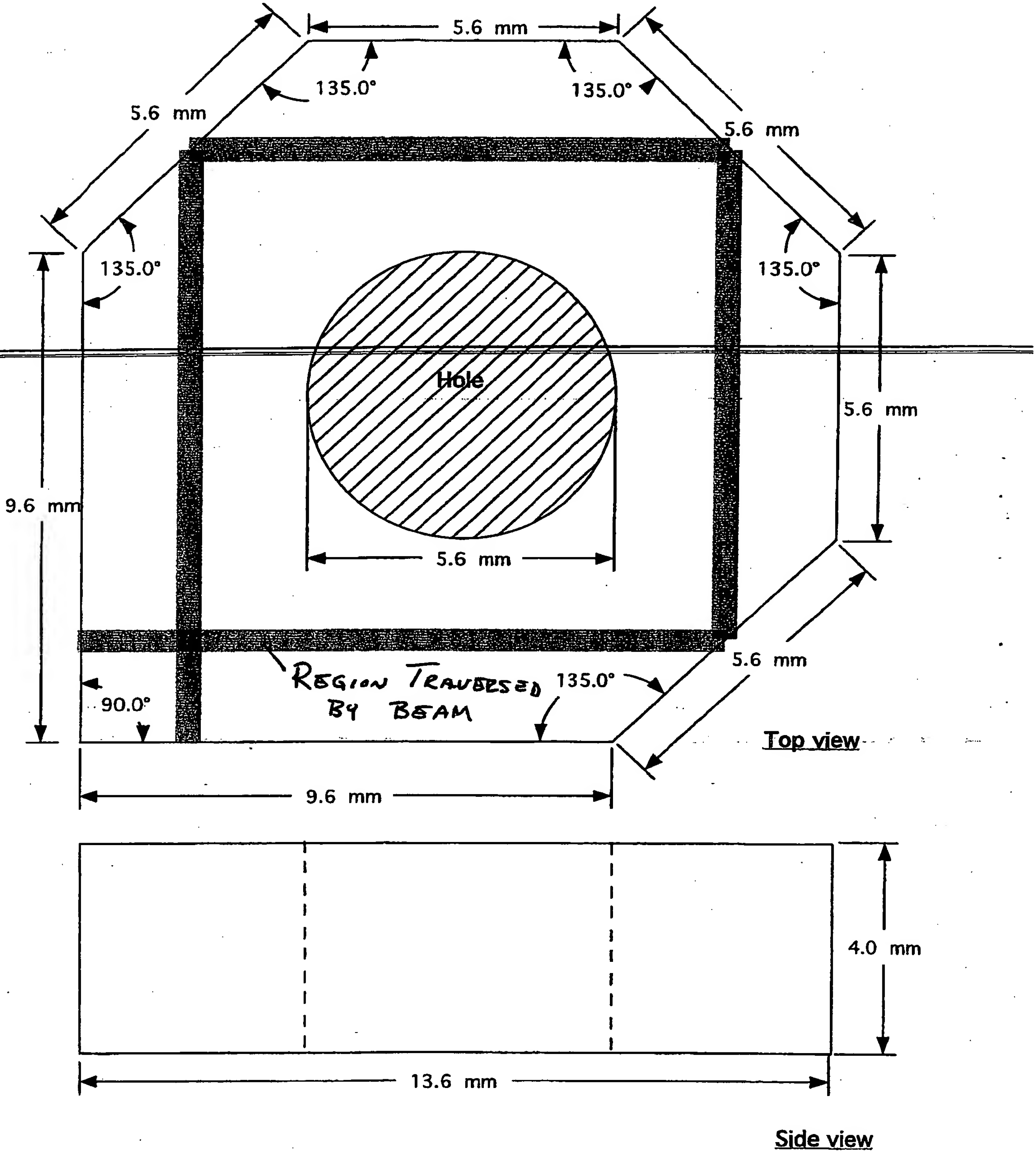
We request a quotation of price and delivery time for the fabrication of piece described in the accompanying drawing.

| | |
|---|---|
| Number of pieces: | 6 |
| Material: | Nd:YAG |
| Doping: | 1.4-1.5 at. % Nd doping<br>Please inform if there is material with a concentration near this which is already available. |
| Transmitted wavefront: | λ/8 P-V per inch wavefront distortion (specify other if this is not attainable). The area to be traversed by beam is indicated on drawing. |
| Surface finish: | • Outside faces: Polished—λ/10 P-V surface flatness, Scratch-Dig < 20/10.<br>• Central core surface: ground<br>• Top and Bottom surfaces: ground |
| Bevel: | 45° Top + Bottom edges: specify minimum size |

The accompanying drawing is considered to proprietary information to General Atomics and is provided for the purpose of providing a quotation for its manufacture. No other use or dissemination of this information, except for the purpose of generating a price of fabrication, is allowed.

Contact:
Paul Banks Paul Banks

(858) 455-4270
Fax: (858) 455-3112
Paul.Banks@gat.com


5.6 mm
135.0°
135.0°
5.6 mm
5.6 mm
135.0°
135.0°
Hole
5.6 mm
9.6 mm
5.6 mm
5.6 mm
REGION TRAVERSED BY BEAM
135.0°
90.0°
Top view
9.6 mm
4.0 mm
13.6 mm
Side view



Pg. A2

# EXHIBIT B

# VLOC
SUBSIDIARY OF II-VI INCORPORATED

7826 Photonics Drive, New Port Richey, FL 34655
Phone: (727) 375-8562 Fax: (727) 375-5300

GENERAL ATOMICS

3550 GENERAL ATOMICS CT.
SAN DIEGO CA 92121
USA

ATTENTION: PAUL BANKS (FAX: 858-455-3112)

Date: [redacted]
**Quotation #** 024690
**Reference Quote # on P.O.**
Terms: Net 30
F.O.B.: New Port Richey, FL
Page: 1
THIS QUOTATION VALID FOR 45 DAYS

WE ARE PLEASED TO SUBMIT THE FOLLOWING PRICES AND DELIVERY SCHEDULES:

| ITEM | DESCRIPTION | QUANTITY | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|
| 1.00 | 1.4% ND:YAG SLAB<br>13.6 X 13.6 X 4.0MM THICK<br>WITH 5.6MM CENTRAL HOLE<br>7 OUTER FACES TO BE<br>POLISHED LAMBDA/10;<br>10/5 OVER 95% C.A.<br>CENTRAL CORE, TOP AND<br>BOTTOM FACES: GROUND<br>TRANSMITTED WAVEFRONT:<br>LAMBDA/8/INCH<br>NO COATING<br>ANGLE DEVIATION: < 3 MIN. | 3.00 | 3,000.00 | 9,000.00 |
| 1.00 | 1.4% ND:YAG SLAB<br>13.6 X 13.6 X 4.0MM THICK<br>WITH 5.6MM CENTRAL HOLE<br>7 OUTER FACES TO BE<br>POLISHED LAMBDA/10;<br>10/5 OVER 95% C.A.<br>CENTRAL CORE, TOP AND<br>BOTTOM FACES: GROUND<br>TRANSMITTED WAVEFRONT:<br>LAMBDA/8/INCH<br>NO COATING<br>ANGLE DEVIATION: < 3 MIN. | ~~6.00~~ 5 | 2,335.00 | ~~14,010.00~~ ~12,300 |

DELIVERY: 6 WEEKS

Sales Rep.: [signature]
PHIL DREW

# EXHIBIT C

1858 457 8787 # 247 29

# VLOC

*Subsidiary of II-VI Incorporated*
7826 Photonics Drive, New Port Richey, FL 34655
Telephone 727-375-8562 * Fax 727-375-5300

## Shipping Packlist

Page 1.00

Current Date [redacted]
Cust. Ord. Packlist ID: 32927
Cust. ID: GENERAL ATOMICS
Cust. Order ID.: 15322
Order Date: [redacted]

Ship To:
**GENERAL ATOMICS**
**C/O CENTRAL RECEIVING**
**3483 DUNHILL STREET**
**SAN DIEGO CA 92121**
**USA**

Cust. P/O Ref#.: **H028402**

Export of these items must be made in accordance with all U.S. export laws and regulations. Diversion contrary to U.S. law prohibited.

Ship Via: UPS RED
FOB:
Terms: Net 30

Cust.Des.Shp.Date [redacted]
Sale Rep. PD

| Line# | Ord. Qty | Shp Qty | Bck Ord. Qty | Part ID | Part Description |
|---|---|---|---|---|---|
| 1.00 | 5.00 | 5.00 | 0.00 | 986393-GENERAL A | YR1.4-13.6X13.6-4.0FP-C WITH 5.6MM CENTRAL HOLE UNCOATED |

GENERAL ATOMICS
MAIN REC.

[redacted]

PROJECT ... FICATION

UPS

Pg. C1

**GENERAL ATOMICS**

# PROCUREMENT REQUISITION

PURCHASE ORDER NO. Tax [illegible]

JA

RECOMMENDED OR PREVIOUS SUPPLIER: VLOC

SEE COMPANY POLICY MANUAL CP-600 AND THE REVERSE SIDE OF THIS FORM FOR INSTRUCTIONS

| ITEMS FROM | ITEMS TO | DISTRIBUTION ACCOUNT | ORG | WORKORDER |
|---|---|---|---|---|
| 1 | 1 | 7101.0001 | | 04437.220 |

CORP CODE: 00169

PR NO. **284487**

1 ☐ NOT FOR RESALE (TAXABLE) (A)
2 ☑ FOR RESALE (NONTAXABLE) (R)
3 ☐ TAX NOT APPLICABLE (NONTAXABLE) (N)

FINANCE REVIEW (TYPE OR PRINT NAME AND SIGN): Vandergunter [redacted]

SHADED AREA FOR PURCHASING USE

1070 VLOC

REQUESTED BY: Paul Banks

DATE: [redacted]

LOCATION: 13-266 | EXT: 4270 | ORG NO.: 499

REQUESTED DELIVERY DATE: [redacted]

DELIVER TO: Requestor | EXT: | LOCATION:

PR APPROVAL (TYPE OR PRINT NAME AND SIGN): [signature]

DATE APPROVED: [redacted]

QUALITY INSTRUCTIONS
☐ SOURCE INSPECTION REQUIRED
☐ RECEIVING INSPECTION REQUIRED

QA REVIEW (TYPE OR PRINT NAME AND SIGN): M. G. Dunn [redacted]

| ITEM | SOLE SRC WO | QUANTITY | UNIT MEAS | ESTIMATED UNIT COST | DESCRIPTION INDICATE MANUFACTURER, ETC. UNDERLINE VENDOR CATALOG/PART NO. IF APPLICABLE | PART NO./DWG NO. ☒ GA ☐ VENDOR | PROP TAG Y N |
|---|---|---|---|---|---|---|---|
| 1 | | 5 | EA | — | 7-sided Nd:YAG slab<br>– See attached sketch + specifications<br>– Quote 024690 attached | | |

RECEIVING COPY

ESTIMATED TOTAL PR VALUE: 12,6300

RECEIVING INFORMATION Comp [redacted] Camm

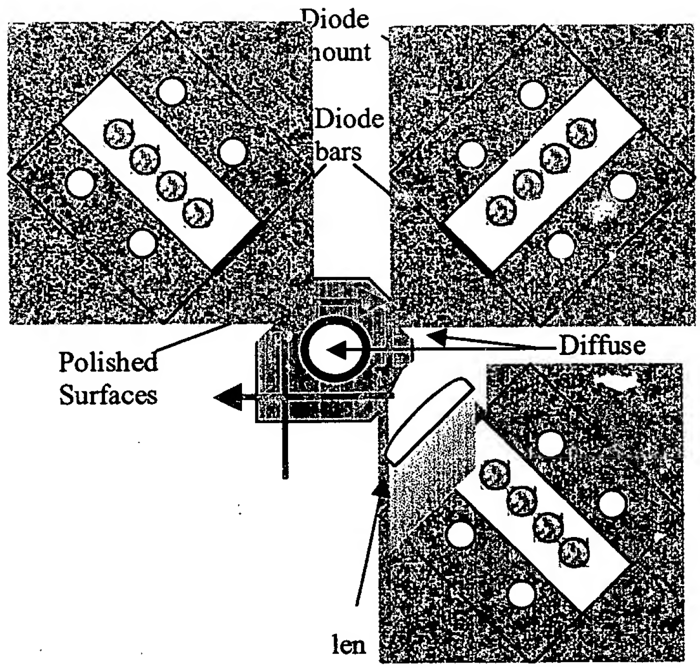
| DATE | ITEM | QUANTITY REC'D | QUANTITY ACC | SHIP NO. | B/L NO. | INITIAL | DATE | ITEM | QUANTITY REC'D | QUANTITY ACC | SHIP NO. | B/L NO. | INITIAL | DATE | ITEM | QUANTITY REC'D | QUANTITY ACC | SHIP NO. | B/L NO. | INITIAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [redacted] | 1 | 5 | | 1 | / | VC | | | | | | | | | | | | | | |

RETURNED GOODS

| ITEM | QTY | SHIPPING ORDER NUMBER | DATE | ITEM | QTY | SHIPPING ORDER NUMBER | DATE | ITEM | QTY | SHIPPING ORDER NUMBER | DATE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |

pg. C2

# EXHIBIT D



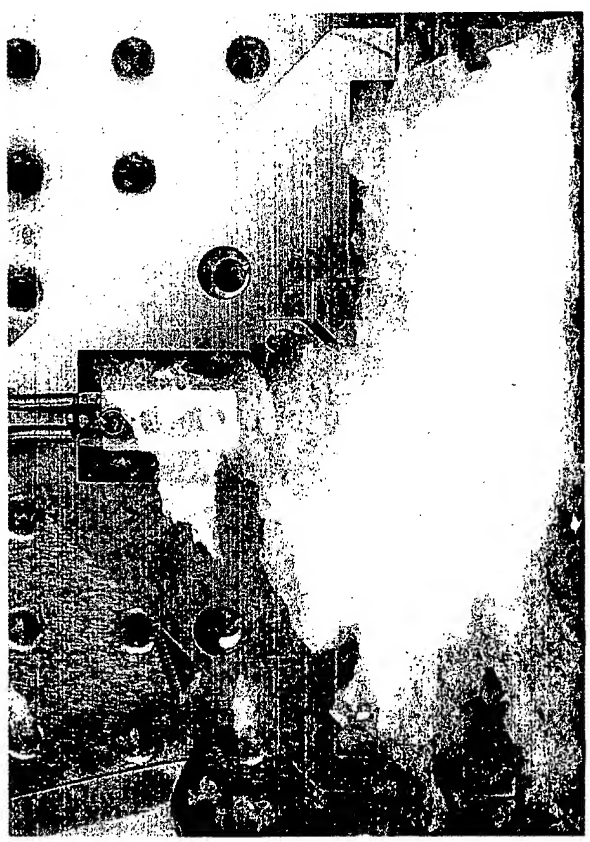
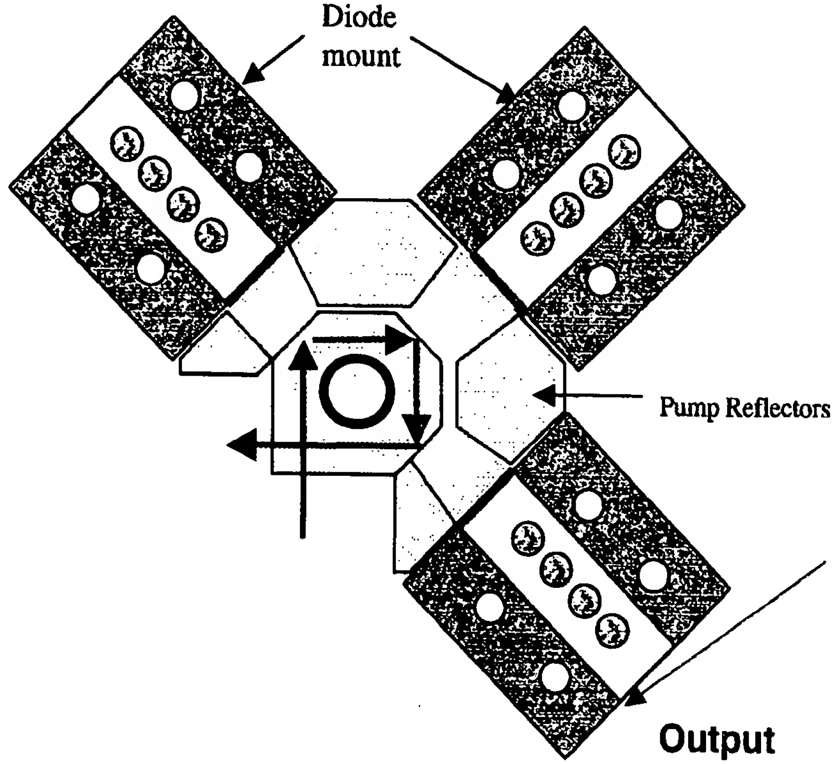
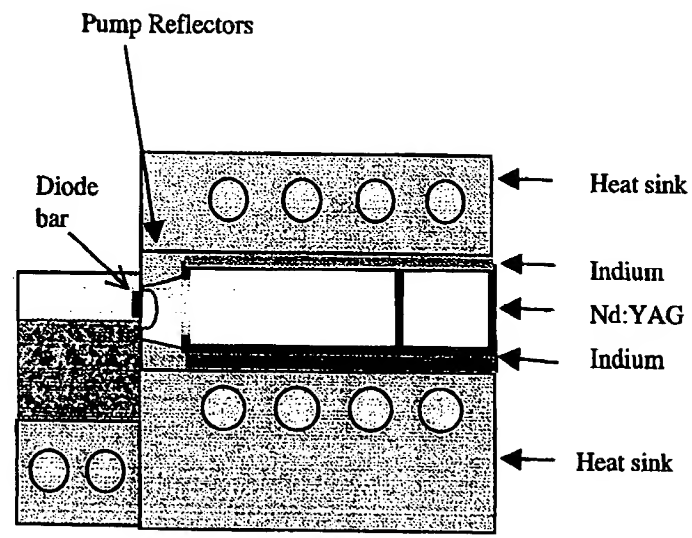



Figure: First reduction to practice of App. No. 09/801,428 – [redacted]

# EXHIBIT E

# This design concentrates deposited energy uniformly across the beam spatial profile



# EXHIBIT F

QTYUIOP

[redacted]

To: Mike Perry

From: Paul Banks

RE: Laser energetics calculations for sapphire amplifier design

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This memo is to summarize what has been done on the amplifier module for the Sapphire product line. Most of the effort has concentrated on the 7-sided slab you described in your note from [redacted] The shape is shown in Fig. 1, and has an overall dimension of 13.6 mm x 13.6 mm x 4 mm thick. Each face is 5.6 mm x 4 mm and the clear aperture for the beam is a 4 mm square. It can be pumped either by 3 diode bar assemblies as shown in Fig. 1 or by 5 bar assemblies by adding an additional bar at each of the two unused faces. In either case, the arrangement is symmetric for the lateral dimension of the beam. The size was principally determined by the beam size for a 10 mJ pulse at 1.2 times saturation fluence in Nd:YAG. The main geometric challenge is to reshape the diode bar output to most uniformly fill the 5.6 mm x 4 mm faces. The major design goal is to amplify a one ns pulse with gaussian spatial profile to approximately 10 mJ.

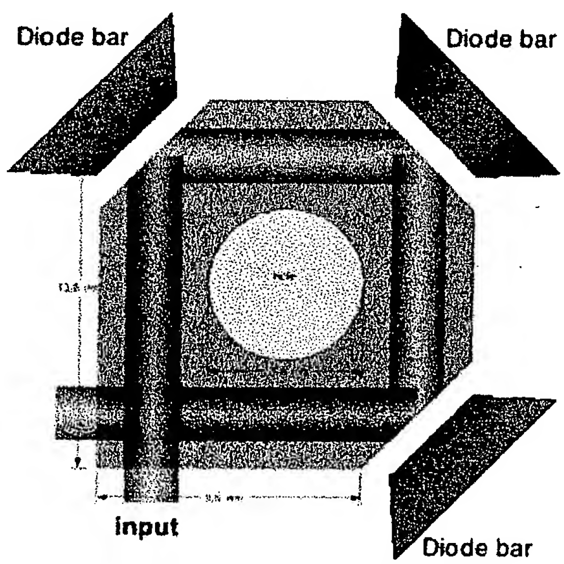



Fig. 1. Top view of amplifier slab

To assess the performance of this design, we developed a 2-d computer model to calculate the distribution of the excited population density due to absorption of the pump light (assuming uniform illumination across the face) as well as saturated gain. The model also includes the decrease in excited population density due to spontaneous decay during the pump pulse because of the finite upper state lifetime. Further amplification of this spontaneous emission in neglected. The decrease in population as the energy is extracted is tracked in order to allow the calculation

of the gain for multiple passes. This also is used to calculate the difference in gain at reflection where portions of the beam travel through regions where the excited population has already been depleted. However, the effect of the beam overlap (resulting in a local increase in energy density) because of the non-zero pulse length at reflections has been neglected. Finally, the effect of the central hole on the absorbed energy distribution has been ignored.

### *General material characteristics*

This computer model was used to compare the relative performance of three materials: Nd:YAG, Nd:YLF, and Nd:$YVO_4$ with several Nd concentrations for each material. Material parameters for these three crystalline materials is given below in Table 1 (see Koechner, 1999).

Table 1. Material characteristics

| | Nd:YAG | Nd:YLF | | Nd:$YVO_4$ | |
|---|---|---|---|---|---|
| | | $\sigma$ | $\pi$ | $\sigma$ | $\pi$ |
| Nd density (at 1 at. %) | 1.38 x $10^{20}$ $cm^{-3}$ | 1.38 x$10^{20}$ | | 1.25 x$10^{20}$ | |
| Upper state lifetime | 230 $\mu s$ | 520 $\mu s$ | | 100 $\mu s$ | |
| Lower state lifetime | < 200 ps | 10 ns | | < 200 ps | |
| Thermal cond. (W/cm-K) | .14 | .06 | | .05 | |
| Laser wavelength (nm) | 1064.1 | 1053 | 1047 | 1064.3 | 1064.3 |
| Index of refraction | 1.82 | 1.4481 | 1.4704 | 1.958 | 2.168 |
| Emission cross section | 2.8 x $10^{-19}$ $cm^2$ | 1.2 x $10^{-19}$ | 1.8 x $10^{-19}$ | | 15.6 x $10^{-19}$ |
| Absorption cross section | 2.9 x $10^{-20}$ $cm^2$ | 2.2 x $10^{-20}$ | 6.5 x $10^{-20}$ | 8.4 x $10^{-20}$ | 32.6 x $10^{-20}$ |
| Absorption peak | 808 nm | 797 nm | 792 nm | 808 nm | 808nm |
| Absorp. coef (1 at. %) | 4 $cm^{-1}$ | 3 $cm^{-1}$ | 9 $cm^{-1}$ | 10 $cm^{-1}$ | 40 $cm^{-1}$ |

Nd:YAG is the most commonly used of these three crystals. It has relatively high gain and is resistant to thermal fracture. The thermal conductivity is also relatively good. It has a main absorption peak at 808 nm which is actually composed of three peaks at 804, 808, and 812 nm. The relative strengths of the three peaks are .72, 1, and .4, respectively. However, thermally induced birefringence can cause depolarization losses at high average powers.

Nd:YAG is available in high-quality crystals with specifications for wavefront distortion better than $\lambda/10$ per inch. Boules up to 50 mm x 100 mm are commonly available, but there are boundaries in a hexagonal pattern from the core which cause increased wavefront distortion. This limits the largest piece that can be fabricated. Nd concentrations are available from approximately .5-1.5 at. % due to limitations in how the Nd replaces the Y during the growth process.

Nd:$YVO_4$ is birefringent and has very large absorption and emission cross sections. No data were available on the thermal conductivity, but vanadate is known to have issues with thermal lensing. The absorption bandwidth of vanadate is very large (approximately 20 nm) making it insensitive

to changes in pump diode wavelength. It's short Large crystal sizes are difficult to achieve; the maximum boule size available from VLOC is approximately 13 mm in diameter.

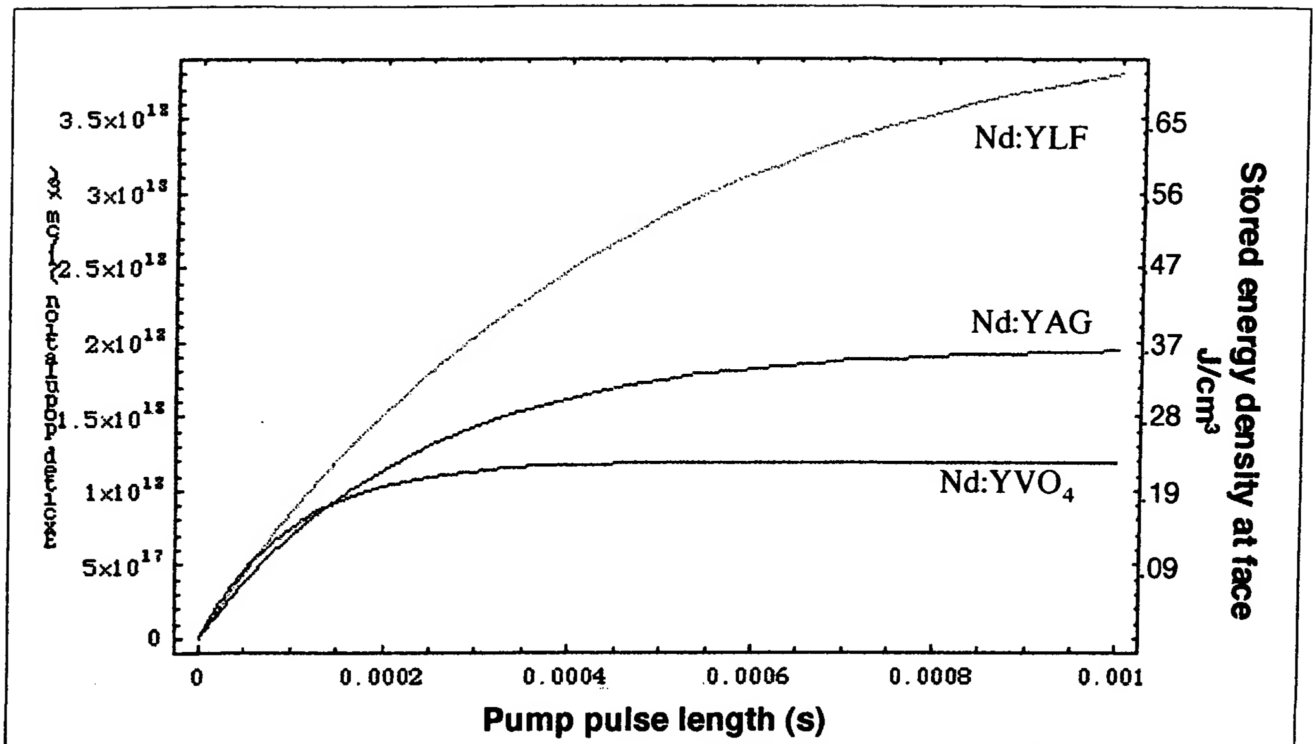
Nd:YLF is also birefringent and exhibits less thermal lensing. However, it is structurally much weaker than YAG and, because of reduces thermal conductivity, is more susceptible to thermal fracture. In fact, 1-d thermal calculations indicate that fracture will limit diode power to levels below those required for high gain. One relatively unusual issue with Nd:YLF is that it has a long lower state lifetime (approximately 10 ns) which will lead to bottlenecking for pulse lengths of this time scale or shorter. This counteracts the long upper state lifetime which increases the energy storage for YLF with diode pumping.

### *Comparison calculations*

A series of comparison calculations, varying pump pulse length and Nd doping concentration, of the gain in these materials was done under a set of nominal conditions. The results are summarized in Table 2. For this set of calculations, a pump pulse (a square wave) was assumed to uniformly fill each of the three 5.6 mm x 4 mm pump faces. 60 W of pump power per face was initially assumed, but it was quickly determined that this was too low for all but vanadate to achieve reasonable gains so a pump power of 80 W/face was assumed. The input pulse was assumed to be a flattop of 2 mm diameter with a uniform fluence of 32 mJ/cm$^2$. This corresponds to 1 mJ in a circular beam. However, all pulse energy values reported in this section are extrapolated assuming vertical uniformity, i.e. the 2-d slab is multiplied by the 4 mm thickness of the crystal. This gives an input pulse energy of 2.4 mJ. This extrapolation is valid for comparison purposes, but it overestimates what can actually be achieved.

Also for these calculations, a three-level system was used to model Nd:YLF because of the long lower state lifetime. Previous measurements have indicated that the effect of this long lower-state lifetime is significant for amplified pulse lengths of even 15-20 ns. Because our intended pulse length is approximately 1 ns, it is reasonable to assume that the effect will be even greater and that YLF will behave as a three-level system. However, this will not be entirely correct when used in a multiple-pass amplifier design because the finite time between each pass will permit some depopulation of the lower laser level, thereby improving the performance of this material above that which is predicted here.

First, the achievable gain is sensitive the pump pulse length used, which for CW diodes is related to the repetition rate. Fig. 2 shows the calculated excited population density (and stored energy density) at the face of the crystal as a function of the length of the pump pulse. These curves saturate for times longer than approximately twice the upper state lifetime of the material in question. This indicates that energy deposited over time scales longer than this will have little effect on amplification and will go to either waste heat or to amplified spontaneous emission (ASE). This can be seen in Table 2 where the calculated stored energy decreases significantly as the pulse repetition rate is increased from 1 kHz to 3 kHz in YLF. The decrease is less dramatic in YAG, and almost negligible in $YVO_4$.




Fig, 2. Excited population density at crystal face for three crystals types: Nd:YAG, Nd:YLF, and $Nd:YVO_4$ (80 W in a 1 ms pulse, 1.5 at. % Nd)

The calculated spatial distribution of the excited population density is illustrated in Fig. 3 for 1.5 at. % Nd:YAG with 1 ms pump pulse from 3 80 W diode bars. Spreading in the pump beam due to diffraction or the 5° angular divergence of the diode bar slow axis has been neglected as have reflections from the central core walls. Most of the stored energy is concentrated near the three pump faces of the crystal, with little excited population near the central core. As indicated in Table 2 under the maximum value for "N(2)" (the excited population density), materials with higher absorption coefficient (either by increased doping or higher absorption cross section) preferentially concentrate the stored energy nearer the face, with correspondingly less near the center. This is significant because the beam path in this design traverses the region near the pump faces, but not the region surrounding the central core (see Fig. 1). The percentage of the stored energy which lies within the region traversed by a 2 mm beam is indicated in Table 2 under "Fraction stored E in vol". This gain-mode volume overlap increases with the absorption coefficient from 47% for one pump polarization in Nd:YLF to 71% for $\pi$-polarized pump light in $Nd:YVO_4$. It should be emphasized that this quantity applies only to the two-dimensional slice used in these 2-d calculations. For the actual beam and stored energy distributions, the overlap will be smaller.

However, for this latter case of 75% overlap, the gradient in the population density becomes steep enough to begin to impact the spatial distribution of the gain. An interaction between the population density gradient, depletion of the inversion, and gain saturation results in a spatial dependence of the fluence after 4 passes which has a total spread of 17%. This nonuniformity in the gain is unacceptably largeand so there must be an optimal pump absorption which will maximize the overlap without unduly affecting the spatial uniformity of the gain. Table 2 shows

the relative spatial uniformity after 8 passes (except for Nd:$YVO_4$ which is after 4 passes); it is between 5 and 8% except for the case in $YVO_4$ mentioned above.

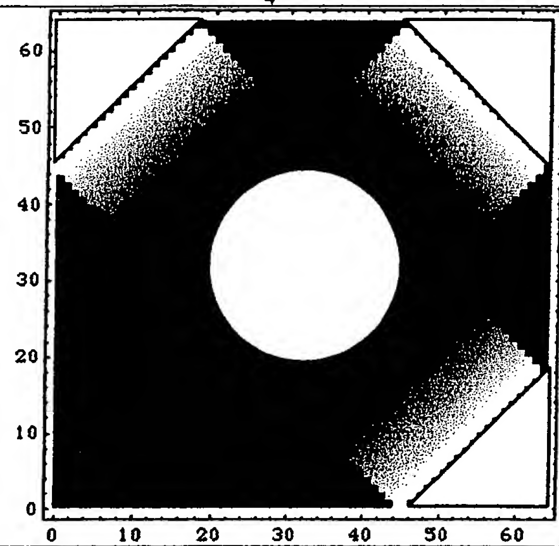



Fig. 3. Top view of spatial distribution of excited state population density pumping from three faces. Light color indicates higher inversion density.

From these calculations, it becomes apparent that Nd:$YVO_4$ is best for high repetition rate applications, but it cannot store enough energy to achieve output pulse energies of 10 mJ. Its high gain also is useful to amplify low energy pulses in a few passes. This could be a pre-amplifier combined with a low energy oscillator to get to the mJ pulse energy level.

There is little energy performance difference between YAG and YLF even though YLF can store twice as much energy. Mechanical calculations by Matt Kendall also indicate that it is likely that YLF would fail using 80 W to pump each faces from thermal stress. We have decided to use YAG for this amplifier design, although the depolarization losses induced from thermal birefringence is still unknown.

The choice of YAG impacts the choice of a pump source. Because of the upper state lifetime of 230 $\mu$s, pump pulse lengths longer than approximately 400-500 $\mu$s result only in lost efficiency and a higher heat load. This means that if CW diodes are used, the system should operate at repetition rates higher than 2 kHz. However, CW diodes are not yet available in powers greater than 60 W. Using 2-diode arrays on each face presented issues with the minimum spacing between bars being approximately 2 mm. Finding a manufacturer to package such arrays also is problematic. For these reasons, we have chosen to use QCW bars which can deliver up to 100 W of power with a 20% duty cycle. Coherent Laser was able to provide such bars and has the reputation of meeting their delivery and optical requirements.

### *Comparison with side-pumped rod*

As a point of comparison, similar calculations were done for rod/slab design which is pumped on both sides by two diode bars as shown in Fig. 4(a) with the beam path down the center of the gain medium. To maintain the same total pump power as used in the calculations discussed to

# EXHIBIT G

PER 10ms PW: 300µs $\frac{1.68+V}{1.68}$ = GAIN

100HZ

| | | | |
|---|---|---|---|
| 25° | GAIN @ | 40A | NEG |
| " | " | 100A | 0.4mV |
| 35° | " | 40A | 0.0mV |
| " | " | 100A | 0.7mV |

PER 1000µs PW: 300µs

1KHZ

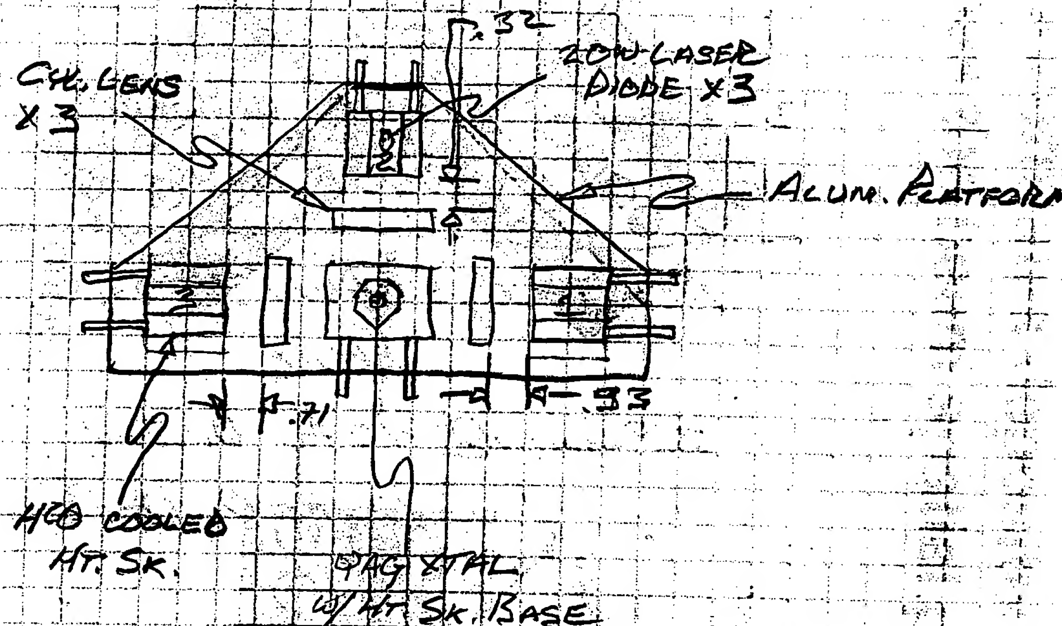
| | | | |
|---|---|---|---|
| 35° | GAIN @ | 40A | 0.15mV |
| " | " | 100A | 0.4* |

RG = ~~SCOTT~~ (HSIEH)?
RACK

$$\frac{1.68+V}{1.68} = GAIN$$

# SAPPHIRE LASER
## TEST SETUP

3 - DIODE LASERS PUMP YAG
AMPLIFIER XTAL




POSSIBLE NESLAB HX150 $H_2O$ CHILLER BLDG. 34-2
DIODE REQ. 80W HT. SK. EA. = 240W TOTAL
+ YAG COOLING 50 PSI @ CENTRIFUGAL PUMP
1/8" HOSE FROM MANIFOLD TO HT. SKS.
INDIUM FOIL (.002 THK.) USED AS TERMAL CONN.
FOR DIODES AND YAG XTAL (HT. SK. GREASE NOT
RECOMENDED) — THERMOCOUPLES (TYPE K) OR
CALIBRATED THERMISTERS FOR TEMP. MONITOR
CURRENT MONITOR ALSO NEEDED.

[redacted]

~~1 Pg. B-O 84 WED~~

~~Discuss Shahyre~~

~~Consult Matt K~~

~~2 - 1/4 NPT - 3/8 SWAG~~

~~TRACKING 408-764-4000~~ COHERENT

~~12 - 1/8 NPT - 1/8 SWAG~~

~~1/4 NPT x 3/8 ST/90°~~

~~2-5G 4-MO~~

~~SKW - WESLAB DIAG? JOHN LOWR~~

~~10 - NYLON SCREWS~~

~~12 GA. WIRE BLK, RED 50'~~

~~LAB PWR SUPPLY 3.0V@ 100A~~

~~NEED REVERSE DIODE~~

p. G3

[redacted]